

Associated absorption and radio source growth

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Abstract.

Results are presented from a survey for C IV associated absorption in a complete low-frequency-selected sample of quasars. In agreement with previous work, associated absorbers are most common in steep-spectrum and lobe-dominated quasars, indicative of an anisotropic cloud distribution. Furthermore, we find the strongest C IV absorption occurs in sources of small radio size, suggesting that the absorbing clouds are destroyed or displaced as radio sources expand. Evidence for dust in the clouds is also found, such that quasars with strong absorption are systematically redder. Finally, we find no evidence for evolution in the frequency or properties of the absorbers from $z \sim 0.7$ to $z \sim 3$.

1. Introduction

Absorption lines occurring very close to the quasar redshift — associated absorbers — are potentially valuable probes of quasar environments. The precise origin of the absorbing material is unknown, but many interesting regions along the sightline may contribute. Absorption may arise, for instance, in gas near the quasar nucleus, in the ISM of the host galaxy or in neighbouring galaxies.

It seems clear that the majority of associated absorption systems (as defined by $|z_a - z_e| < 5000 \text{ km s}^{-1}$) are related directly to the quasar phenomenon, rather than being due solely to cosmologically-distributed foreground galaxies. First, the density of associated absorption systems per redshift interval is greater than expected for intervening galactic systems alone (Foltz et al. 1988, Richards et al. 1999, 2001). Secondly, the characteristics of the absorbers depend on quasar type. Narrow absorption lines occur more frequently in radio-loud quasars, especially those with steep radio spectra (Anderson et al. 1987; Foltz et al. 1988; Richards et al. 1999, 2001). Alternatively, optically-selected samples might be biased against objects with absorption. Previous studies have interpreted the prevalence of $z_a \approx z_e$ systems in steep-spectrum and lobe-dominated quasars in terms of orientation (Barthel, Tytler & Vestergaard 1997). In addition, $z_a \approx z_e$ systems differ subtly in ionisation or velocity profiles from those seen along sightlines traversing normal galaxy halos, consistent with their proximity to the AGN (Hamann & Ferland 1999).

A major limitation of most previous studies of $z_a \approx z_e$ absorption is that they have used inhomogeneous samples which are prone to strong selection effects. To counter this, we have observed $z_a \approx z_e$ absorption in quasars drawn

from a complete sample of 408-MHz selected quasars. Low-frequency radio selection and a high completeness level ensure that orientation bias is minimised and reddened sightlines are included. The initial results of this study, correlations between C IV absorption and quasar properties, are summarised here. Full results will be published shortly (Baker et al. 2001, in preparation). Cosmological parameters $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega = 1.0$ and $\Lambda = 0$ are assumed for consistency with our earlier work.

2. The quasar sample and observations

We have obtained intermediate-resolution spectroscopy of the C IV to Ly α spectral region for 43 quasars drawn from the complete Molonglo Quasar Sample (MQS; Kapahi et al. 1998; Baker et al. 1999). Briefly, the MQS comprises all quasars in the $-30^\circ < \delta < -20^\circ$ strip of the 408-MHz Molonglo Reference Catalogue (MRC; Large et al. 1981) down to a limiting flux density of $S_{408} = 0.95 \text{ Jy}$. The MQS contains 111 quasars with $0.1 < z < 3.0$.

MQS quasars were selected for the absorption study in two redshift ranges, $1.5 < z < 3.0$ where redshifted C IV is observable from the ground, and $0.7 < z < 1.0$ which was observed in the UV using STIS on HST. Ground-based spectra with spectral resolution $1\text{--}2.4\text{\AA}$ (FWHM) were obtained for 22 out of a total of 27 MQS quasars with $z > 1.5$, using mostly the Anglo-Australian Telescope (AAT) and the ESO 3.6m telescope. In addition, four faint quasars were observed with FORS1 on the VLT (UT1). The STIS spectroscopy was carried out between May 1999 and February 2001 for 19 MQS quasars with redshifts $0.7 < z < 1.0$. The NUV-MAMA detector was used with the G230L grism, giving a spectral resolution of 3.0\AA over the wavelength range $1570\text{--}3180\text{\AA}$.

Absorption systems were identified and measured using IRAF. The strongest absorption system was identified in each spectrum within $\pm 5000 \text{ km s}^{-1}$ of the C IV emission-line redshift. The majority (50–70%) of the resulting systems lay within $\pm 500 \text{ km s}^{-1}$ of the emission redshift, and were both blue- and red-shifted.

3. Results

3.1. Radio spectrum and morphology

Although not shown explicitly in this short contribution, we do confirm the trends for absorption to be most prevalent in steep-spectrum and lobe-dominated quasars (e.g. Anderson et al. 1997; Foltz et al. 1988; Barthel et al. 1997). In our MQS study, for example, strong absorption ($W_\lambda > 1\text{\AA}$) was detected exclusively in steep-spectrum ($\alpha > 0.5$) quasars in both the high- and low-redshift subsamples.

3.2. Radio size

In the MQS data, the most striking result is that the strongest absorption occurs preferentially in the smallest radio sources. The equivalent widths of C IV absorption are plotted as a function of radio source size in Figure 1 for both high- and low-redshift datasets. Highly beamed core-dominated quasars are excluded as they are expected to be severely foreshortened. Compact, steep-spectrum

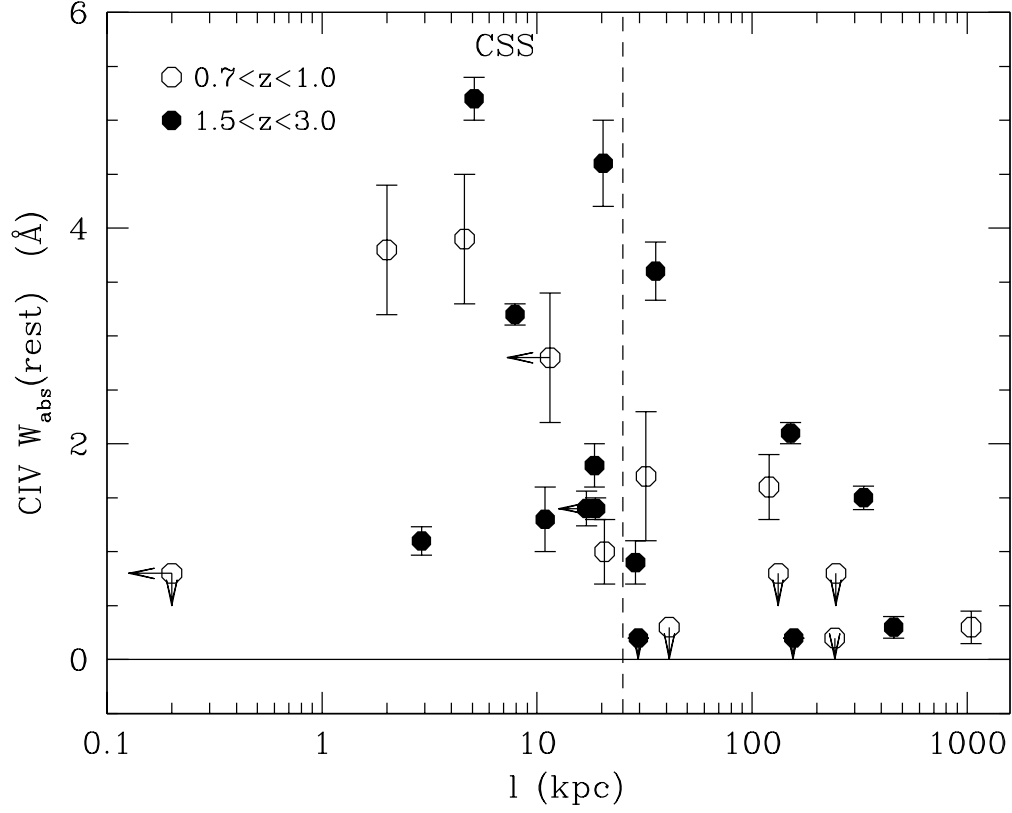


Figure 1. Equivalent width of C IV absorption as a function of radio source size, l (kpc). Quasars with $0.7 < z < 1.0$ are plotted as open circles, those with $1.5 < z < 3.0$ are plotted with filled symbols. The dotted line at $l = 25$ kpc illustrates our working definition of CSSs. Arrows indicate limits.

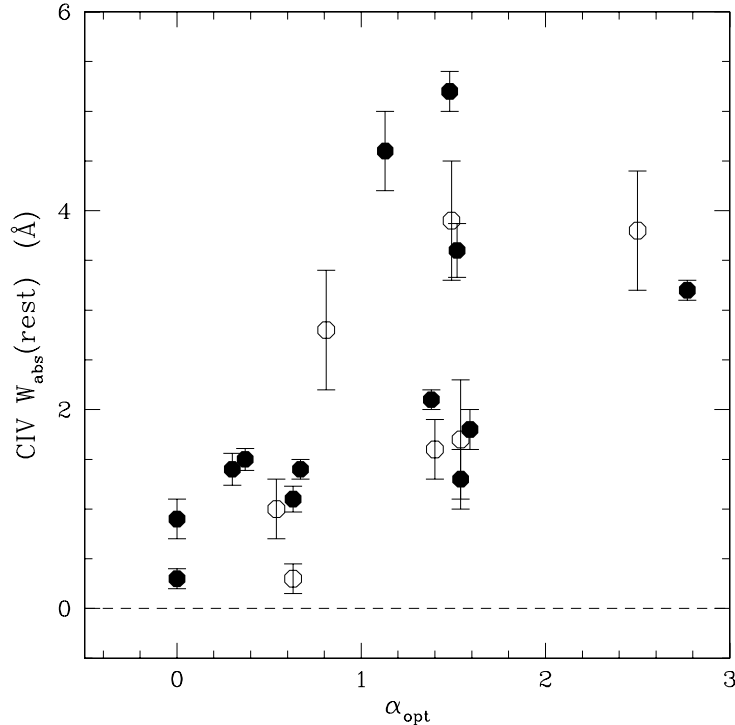


Figure 2. Equivalent width of C IV absorption as a function of optical spectral index, for all quasars with detected absorption. Quasars with $0.7 < z < 1.0$ are plotted as open circles, those with $1.5 < z < 3.0$ are plotted with filled symbols.

(CSS) sources are included on the plot. CSS sources (see review by O’Dea 1998) are intrinsically small ($l < 25$ kpc) with steep radio spectra ($\alpha > 0.5$ where $S_\nu \propto \nu^{-\alpha}$). The precise definition of CSSs is somewhat arbitrary, comprising essentially those sources whose radio emission was unbeamed (not core-dominated) yet unresolved with conventional arrays (arcsec resolution). Thus CSS sources do include intrinsically small, and perhaps young, sources. Radio sizes for the CSS quasars in the MQS study were measured from MERLIN images with $\sim 0.1''$ resolution (de Silva et al. 2001, in preparation). Notably, all the CSS quasars in our study (except an unusual GigaHertz-Peaked Spectrum source) show $z_a \approx z_e$ absorption stronger than $W_{\text{abs}} = 1\text{\AA}$.

3.3. Reddening by absorbing clouds

For quasars where C IV absorption was detected, the equivalent width of the absorption is plotted in Figure 2 against the slope of the optical spectrum, α_{opt} (as observed between 3500 and 10000Å). There is a strong correlation between absorption-line strength and spectral slope — heavily absorbed quasars are systematically redder.

Baker & Hunstead (1995) and Baker (1997) presented evidence that the range in optical spectral slope observed in the MQS is due in part to reddening by an anisotropic dust screen lying outside the broad emission-line region. In this earlier study, the most direct evidence for dust reddening (as opposed to intrinsic spectral steepening) was the tight correlation between α_{opt} and broad $\text{H}\alpha/\text{H}\beta$ Balmer Decrement, at least in low-redshift quasars where it was measurable in the optical. The reader is referred to Baker (1997) for this result and a more detailed description of the dust-reddening hypothesis. By extension, the simplest explanation of the correlation of W_{abs} with α_{opt} is that the absorbing gas clouds contain dust, and they lie outside the nuclear continuum source. Alternatively, if dust is not responsible for the red continuum slopes, then C IV absorption strength correlates with an intrinsically softer continuum shape.

4. Discussion

These results suggest that the distribution of associated absorbers in quasars is dependent on *both orientation and radio size*. Orientation explains the trends with radio spectral index and radio-core dominance, as described by Barthel et al. (1997). Orientation, however, cannot explain the stronger absorption in CSS sources and the global decrease in absorbing column density with radio size.

The radio-size dependence of associated absorption may be explained if the absorption column density either correlates with quasar environmental density, or changes with time. Currently, the first hypothesis is not supported by observations, which find that CSS host galaxies appear to be the same as those harbouring larger sources, and CSS quasars do not systematically reside in clusters more often than larger sources (de Vries et al. 2000; O’Dea 1998 and references therein). The alternative idea is that the absorbing column density decreases as the radio source grows. This could occur because of photoionisation of the clouds by the quasar over time, or by direct interaction of the radio jet and its cocoon on the absorbing clouds, or both.

The strong correlation between the C IV absorption strength and red continuum in the quasars is highly suggestive of dust in the absorbing clouds. However, a cospatial distribution of dust and gas is problematic, dust should be destroyed by sputtering in the hot gas where C IV absorption arises. De Young (1998) points out that the strong shocks in radio-source environments should destroy dust easily on timescales $\ll 10^6$ yrs, which is much shorter than the lifetime of the radio source.

Putting all the evidence together, we propose a consistent model whereby radio sources are born enshrouded in dust and gas, which is gradually destroyed and ionised (respectively) along the radio axis as the source expands.

In addition, we find no evidence for changes in the frequency or strength of the absorbers with redshift from $z \sim 0.7$ to $z \sim 3$. This lack of evolution is perhaps unexpected given the absorbers are probably at kpc distances where they should be affected by quasar environmental and perhaps galactic evolution.

5. Conclusions

Initial results from a study of C IV associated absorption in a complete, homogeneous sample of radio-loud quasars are presented. The results confirm that the absorbing cloud distribution is anisotropic, such that absorption is more common in steep-spectrum and lobe-dominated quasars. Furthermore, we find new evidence that the strength of C IV absorption decreases with increasing radio source size. If we assume that the larger sources are older than the smaller (CSS) ones, then we can attribute the decrease in column density to the growth of the radio source envelope through the ISM. The absorbing clouds probably contain dust, which reddens the quasar light. Consequently we predict that absorbed quasars will be missed preferentially in optically-selected samples. Finally, these results appear to be independent of redshift, giving essentially the same picture at $z \approx 0.7$ and $z \sim 3$, epochs between which evolution of quasar environments should be discernible. Thus we are drawn to a picture where radio sources are born in gaseous and dusty cocoons, from which they emerge as their radio jets expand beyond the host galaxy.

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